Holography Data Reduction
User Documentation

2007-03-21

User Documentation

R. Lucas
Change Record

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1 Introduction

2 Holographic Data Analysis

2.1 Description

The data analysis uses the CLIC data reduction software of the Plateau de Bure interferometer. The raw data, written by the on-line software in ASDM data format, is converted to Plateau de Bure format using CLIC.

The data are then calibrated and imaged using CLIC. The two main operations are:

1. *Calibrate data in amplitude and phase*, based on bore-sight measurements at beginning and end of each map row, assuming gradual drift in amplitude and phase with time. This uses the standard amplitude and phase calibration commands: \texttt{SOLVE PHASE}, \texttt{STORE PHASE}, \texttt{SOLVE AMPLITUDE}, \texttt{STORE AMPLITUDE}.

2. *Compute the aperture map and fit panel displacements and deformations*: This is implemented in command \texttt{SOLVE HOLOGRAPHY}. The mathematics are in §??.

The data processing steps are:

(a) *Interpolate data to a regular grid* in antenna-based coordinate system. This grid matches the observed system of rows (same number and separation). This grid is further extended, by addition of zeroes, to a user-specified size, in order to get a finer interpolation of the output aperture map: 64x64, 128x128, 256x256 and 512x512 sizes are available.

(b) *FFT to aperture plane*. This is replaced by a more complex transformation if one takes into account the first non-Fresnel terms. This is described in §??.

(c) *Compute phases in the aperture plane*.

(d) *Apply the geometrical phase correction*: this is

\[
\Delta \rho = \frac{\rho^2}{2R} - \frac{\rho^4}{8R^3} + \sqrt{\rho^2 + (f + \delta f - \frac{\rho^2}{4f})^2 - (f + \frac{\rho^2}{4f} + \delta f)}
\]

where \( \rho \) is the radius in the aperture, \( f \) the focal length of the primary, \( \delta f \) the refocusing used to compensate for the finite transmitter distance \( R \) (\( \delta f \) is the distance between the holographic horn phase center and the antenna prime focus).

(e) *Correct for measured feed phase diagram*.

(f) *Mask edges and blockage*.
(g) Fit and remove 6 phase terms: constant, 2 linear gradients, 3 focus translations. They account for a phase offset, an antenna pointing error (constant during the measurement) and a small displacement of the holography horn relative to the nominal focus position \(f + \delta f\) above. One may keep fixed either the \(X\) and \(Y\) coordinates or all three \(X, Y, Z\) coordinates.

(h) Convert to normal displacement map.

(i) Plot amplitude and phase maps.

(j) Fit panel displacements (optionally deformations) and screw adjustments. In CLIC we deconvolve for finite resolution effects by an iterative procedure (subtracting the truncated field of the fitted panels from the measurements, to get the next order correction, ...). The screw settings are output in a text file (e.g. testHolography.panels).

2.2 Using the GUI Interface to reduce single-dish holography maps

1. Type `clic` in a terminal window.

A graphic window appears as well as a menu widget. This contains a CLIC menu referring to Holography.

2. In menu CLIC, select ALMA Holography reduction. This causes a dialogue window to appear.
3. Select the data set. This can be done at two levels:

(a) Select a new raw data set: enter the ASDM file name in the “ASDM file name”. This is done by pressing FILE and using the file dialog window that appears. By default this will filter ASDM tar-gzipped files with names like “*.tgz” (sorry, *.tar.gz will not work). Alternately one may select ASDM root directories with names like “*/ASDM.xml”.

Then Press “CONVERT”. This will create a CLIC data file. Its name will be ’name.hpb’ where ’name’ is the name of the name.tgz archive or the name of the ASDM root
directory. If the ASDM data set was in the form of a compressed tar file, it will previously un-compressed and de-tarred. Then the CLIC data file is gzipped to save disk space.

This first set need only be done once for a new raw data set. If you want to reduce a data set again in a new CLIC session, just select the CLIC data file using the “CLIC File name?” file dialog option, and move the the next step. In this dialog box you are free to select *.hpb or *.hpb.gz (gzipped) files.

It is recommended to press “GZIP HPB” when you have finished reducing a CLIC data file, in order to compress it and save disk space. This is not done automatically.

(b) Press “SELECT”. The CLIC data file is first un-gzipped if needed. The ExecBlockId will be displayed in the dialogue window. You should also get a plot of angular offsets versus scan number, similar to this:

4. Press “CALIBRATE”. Amplitude and phase of the boresight measurements will be displayed together with a red curve fit. Enter continue or press CONTINUE at the left of the CLIC

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menu window, if the fit looks all right, in order to store it within the data headers.

It the fit fails, e.g. due to fast variations, or bad points:

— You may change the step of the spline function (SET STEP value, with value in hours), then SOLVE AMPLITUDE PHASE /PLOT, to get a new fit.
— Or you may delete a bad point by finding its observation number:
  — enter CURSOR, point with the mouse to the bad point and type ‘H’. The first number listed will be the observation number (subscan number for ALMA data) n.
  — type E to get out of the cursor mode.
  — Then type DROP n to eliminate this observation (subscan) from the current index.
  — Then type SOLVE AMPLITUDE PHASE /PLOT, to get a new fit.
— When you are satisfied, do not forget to type c (for CONTINUE), so that the calibration
is stored in the CLIC file within the data headers. If by chance you start some other procedure before getting out of CALIBRATE, you may type QUIT to go back to the CALIBRATE procedure level, then type C to finish the calibration. It’s only after typing C that the calibration results are stored and can be used and applied. Once the calibration results have been stored however, there is no need to re-calibrate if you re-open the same CLIC data file later on.

— Deleting a bad point in the way just exposed in only valid inside the CALIBRATE procedure (it works on the ‘current index’ in memory). You may also tag data in the CLIC data file itself once it is opened, by typing e.g.

```bash
find /number 197 199
list
store quality bad
```

In this way subscaens 197 to 199 will be ignored in further data reductions of the same CLIC data file. This operation can be reversed by:

```bash
find /number 197 199 /quality bad
list
store quality good
```

5. Select the map size in pixels (64 to 512). It should be higher than the actual number of rows in the observed beam map, (or information will be lost).

6. Press “SOLVE”. The map should appear in the graphic window.
The map header contains, among other parameters:

- the CLIC file name, and ExecBlockId of the data set
- the Antenna name and make (or type),
- the illumination parameters,
- the phase rms (unweighted and weighted by the amplitude),
- the surface rms (also weighted and unweighted),
- aperture efficiencies (calculated using the observed illumination and the geometrical blockage, for the observed frequency and 230GHz), and the corresponding Jy to Kelvin conversion factors.
- illumination efficiency, spillover efficiency, and phase efficiencies (Ruze factors)
- the surface rms in each ring.

7. Additional parameters in the main window:

- **Fresnel Approximation**: when unselected, some additional terms are included.
— *Do feed Correction*: should always be in. Unselect for testing purposes only.

— *Number of masked panels*: the number of panels to be ignored for the fit and the calculation of RMS surface errors. Their numbers are entered in the box below. The panel numbering scheme is in Appendix ??.

— *Apodize Map*: to apodize the observed map in order to reduce/suppress the ‘ringing’ along the quadrupod legs and map edges. The weighting function is a parabola reaching zero at the map edges.

— *Subtract astigmatism*: to fit and remove a vertical astigmatism component. The removed amount \( a \) in mm appears in the plotted map together with the focus offsets (*Notes*: because of projection effects the peak-to-peak deformation at the edge of the dish would be \( \sim 0.92a \), because the astigmatism function is removed from the observed phase; also any astigmatism at 45-degree position angle would be ignored).

8. Additional input windows (to call them press on e.g. “More input for focus”, and the similar boxes below):

— *Focus offsets*: Enter here the focus offsets in mm. The corresponding corrections are applied to the phase map before fitting for focus displacements. This enables overcoming the \( 2\pi \) discontinuities in the phase map. One may also fix either the \( X \) and \( Y \) focus coordinates, or all \( X, Y \) and \( Z \) to these values.

Note that if you enter too large offsets in this window, the fitting process will not converge, and the map will look arbitrarily bad.

— *Tracking, Pointing*: The input map can be displaced to compensate for pointing errors, if they are larger than a fraction of a beam. Naturally it is preferred to peak up on the transmitter before taking the map. One may also enter a ‘fudge factor’ to correct for a tracking error which changes sign between odd and even rows of the map.

— The next row is used to plot a beam map.
Pressing GO in this panel will produce the following map:

---
The last row is used to plot a beam map of the reference beam. Before doing this you have to create the reference beam map by pressing the button SOLVE_REF_BEAM at the top right, next to SOLVE.

Then Pressing GO in this panel will produce the following map:
which displays the measured signal power from the reference horn at the prime focus, as the antenna is scanned.

9. To obtain the list of screw settings: Press “PANELS”. A file such as 23-nov-2001-Vertex.panels is created (where positive numbers mean that the panels should move towards the subreflector). It contains the screw motions in micrometers. At the end of the calculation the left part of the screen displays the fitted panel shapes, while the right one displays the fit residuals.

10. Specific options for this last step can be seen and entered by pressing “input for
panels”. Additional input include:

- **Modes**: the fitted degrees of freedom for panel fitting; the last two actually deform the panels:

<table>
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<th>Options</th>
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<tr>
<td>New, Iterations</td>
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</tr>
<tr>
<td>Iterative Gain</td>
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</tr>
<tr>
<td>Rings avoided for paraboloid fit</td>
<td>1</td>
</tr>
<tr>
<td>Sectors avoided for paraboloid fit</td>
<td>1</td>
</tr>
</tbody>
</table>

  - **Piston** only 1 translation mode (normal to antenna surface)
  - **Tilts** 3 modes: panel tilts around two perpendicular axes in the tangent plane to the paraboloid are added
  - **Torsion** 4 modes: a panel torsion is added
  - **Boss** 5 modes: the motion of panel center relative to the edges is added.

- **Number of iterations**: usually 5 is OK
- **Iterative gain**: usually 1 works
- **Rings avoided for paraboloid fit**: One may take out specific rings of the paraboloid fit (e.g. to adjust one or several ring relative to the others).
- **Sectors avoided for paraboloid fit**: One may take out specific sectors of the paraboloid fit (e.g. to adjust one sector relative to the others).
11. Sample screw listing (Positive screw settings mean that the panel has to move closer to the primary focus, or “up”):

Output from CLIC\SOLVE HOLO 3
CLIC - 04-OCT-2006 13:14:23 - lucas - Antenna *
TOWER VTX-ALMATI scans 1036 to 1036 (10-FEB-2005) Elev: 8.00

Panel ring n0. 1:
Sec/Pan Screw settings (1-5), [mum]
1-11 3( 2) 5( 2) 15( 4) 23( 4) 12( 2)
2-11 22( 3) 23( 3) 16( 4) 19( 4) 19( 2)
3-11 -9( 2) -9( 2) 19( 4) 19( 4) 7( 2)
4-11 21( 6) 31( 6) 16( 9) 51( 9) 25( 5)
5-11 -1( 6) -3( 6) 9( 9) 3( 9) 4( 5)
6-11 -17( 6) -23( 6) 18( 9) -5( 9) -1( 4)
7-11 6( 9) 4( 9) 9( 13) -1( 13) 6( 7)
8-11 16( 9) 12( 9) 23( 13) 11( 13) 18( 7)
### Panel ring n0. 2:

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<td>19( 3) 18( 3) 16( 4) 15( 4) 17( 2)</td>
</tr>
<tr>
<td>2-21</td>
<td>15( 4) 14( 4) 15( 4) 15( 4) 15( 2)</td>
</tr>
<tr>
<td>3-21</td>
<td>13( 4) 17( 4) 24( 4) 30( 4) 21( 2)</td>
</tr>
<tr>
<td>4-21</td>
<td>18( 5) 22( 5) 19( 6) 25( 6) 20( 3)</td>
</tr>
<tr>
<td>5-21</td>
<td>6( 5) 13( 5) -23( 5) -14( 5) -6( 3)</td>
</tr>
<tr>
<td>6-21</td>
<td>0( 4) 11( 4) 1( 4) 16( 4) 6( 2)</td>
</tr>
<tr>
<td>7-21</td>
<td>2( 5) 6( 5) 11( 5) 17( 5) 9( 2)</td>
</tr>
<tr>
<td>8-21</td>
<td>-3( 5) 4( 5) 21( 5) 29( 5) 12( 2)</td>
</tr>
<tr>
<td>9-21</td>
<td>18( 18) 12( 18) 27( 20) 19( 19) 20( 9)</td>
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<tr>
<td>10-21</td>
<td>28( 5) 28( 5) 10( 5) 10( 5) 19( 2)</td>
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<tr>
<td>11-21</td>
<td>19( 7) 21( 7) 4( 8) 7( 7) 12( 4)</td>
</tr>
<tr>
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### Panel ring n0. 3:

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</tr>
<tr>
<td>1-32</td>
<td>16( 3) 17( 3) -2( 3) 0( 3) 7( 1)</td>
</tr>
<tr>
<td>2-31</td>
<td>11( 5) 15( 5) -2( 5) 4( 5) 7( 2)</td>
</tr>
<tr>
<td>2-32</td>
<td>4( 3) 6( 3) 5( 4) 8( 4) 6( 2)</td>
</tr>
<tr>
<td>3-31</td>
<td>12( 5) 12( 5) 7( 5) 7( 5) 9( 2)</td>
</tr>
<tr>
<td>3-32</td>
<td>7( 5) 10( 5) -7( 6) -2( 6) 2( 3)</td>
</tr>
<tr>
<td>4-31</td>
<td>9( 6) 15( 6) 5( 8) 15( 8) 11( 3)</td>
</tr>
<tr>
<td>4-32</td>
<td>6( 6) 11( 6) 8( 6) 15( 6) 10( 3)</td>
</tr>
<tr>
<td>5-31</td>
<td>18( 6) 20( 6) 12( 7) 16( 7) 17( 3)</td>
</tr>
<tr>
<td>5-32</td>
<td>12( 8) 14( 8) 4( 8) 6( 8) 9( 4)</td>
</tr>
<tr>
<td>6-31</td>
<td>13( 8) 17( 8) -1( 9) 4( 9) 8( 4)</td>
</tr>
<tr>
<td>6-32</td>
<td>-29( 8) -11( 8) -32( 10) -6( 10) -19( 4)</td>
</tr>
<tr>
<td>7-31</td>
<td>12( 3) 8( 3) 2( 4) -5( 4) 4( 2)</td>
</tr>
<tr>
<td>7-32</td>
<td>3( 6) 7( 6) 5( 7) 12( 7) 7( 3)</td>
</tr>
<tr>
<td>8-31</td>
<td>8( 3) 6( 3) 0( 3) -3( 3) 2( 1)</td>
</tr>
<tr>
<td>8-32</td>
<td>14( 3) 12( 3) 1( 3) -2( 3) 6( 1)</td>
</tr>
<tr>
<td>9-31</td>
<td>1( 4) -3( 4) 8( 5) 3( 5) 2( 2)</td>
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</table>
9-32  7( 4)  4( 4)  6( 4)  2( 4)  5( 2)
10-31  8(16)  9(16) -2(19)  0(18)  3( 8)
10-32 12( 4)  7( 4)  2( 5) -7( 5)  3( 2)
11-31 18( 3) 19( 3)  4( 3)  5( 3) 11( 1)
11-32 17( 4) 13( 4)  7( 4)  2( 4)  9( 2)
12-31  0( 3)  1( 3)  0( 3)  1( 3)  0( 1)
12-32  1( 4)  2( 4) 14( 4) 15( 4)  9( 2)

Panel ring n0. 4:

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<th>Screw settings (1-5), [mum]</th>
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<td>6( 5) 6( 5) -7( 5) -8( 5) 1( 2)</td>
</tr>
<tr>
<td>1-42</td>
<td>12( 3) 6( 3) -1( 3) -9( 3) 4( 1)</td>
</tr>
<tr>
<td>2-41</td>
<td>-6( 3) -2( 3) -5( 3) 0( 3) -3( 2)</td>
</tr>
<tr>
<td>2-42</td>
<td>4( 3) 3( 3) -1( 4) -3( 4) 1( 2)</td>
</tr>
</tbody>
</table>

... and so on until:

12-81 3(11) -3(11) -6(11) -13(11) -5( 5)
12-82 -16( 6) -21( 6) 32( 6) 26( 6) 5( 3)
12-83  -9( 4) -26( 4) 13( 4) -7( 4) -7( 2)
12-84 -29( 8) 3( 8) -37( 8) -2( 8) -16( 4)

12. In addition a CalDM (Calibration Data Model) result is created (e.g. testHolography-Result.sdm) that is ready to be sent to the Archive using CalDMimport. The CalDM result directory name is built from the ASDM directory name, by adding “-Result.sdm”. Just e.g. type: CalDMimport testHolography-Result.sdm to archive the result.

This result contains in its ASDMBinary sub-directory two FITS files (holographyBeam.fits and holographyMap.fits which are the FITS translation of the .map and .beam Gildas image files produced by CLIC. They could be used to access the beam and surface maps using other data reduction packages, if necessary.

3 Further analysis of maps

There are four other procedures available from the menu:

Map View This is to display surface maps. One may choose to display the panel displacement required, the surface error, the raw phases, the phase residuals (after focus fitting), the
raw amplitude, the fitted amplitude (Gaussian amplitude beam). For each there is a
default scaling and a manual scaling of the plotted quantity. This quantity can also be
dumped into an ASCII file. Surface rms is calculated and displayed. Panel layout can be
overlaid on the map.

— One the map is displayed, typing DRAW enters the cursor mode. Pressing V on a cursor
position display the plotted map value at this point, together with the coordinates of
the point in meters as ”User Coordinates” (Note: please ignore the labelling “rad.”;
ignore also RA and DEC mentioned just below! ).
— Under the cursor, typing T can be used to annotate the plot.
— Type E to leave the cursor mode.

Map Differences This is to display the differences between two maps. Basically the same
choices as with the Map View can be made.

Map Averaging Thsi is used to average several maps for display. In a first dialog, one first
enters a file filter to build a list of files. In a second dialog window, the resulting maps
can be selected to be averaged into the new map. Thsi map can then be displayed using
Map View above.

Beams This is used to display beam maps in a way similar to the surface maps.
A Panel and Screw Numbering for the VertexRSI Antenna

Panels are referenced as ss-rp, where:

- **ss** = Sector number, There are as many sectors as panels in inner ring (12). They are numbered 01 to 12 starting from right, anti-clockwise, when looking at the primary reflecting surface from the primary focus.

- **r** = ring number, from 1 (inner) to 8 (outer).

- **p** = panel position – 1 to 4, anti-clockwise from the same viewpoint, in sector ss along ring r.

- On each panel, there are five adjusting screws, numbered 1 to 5:
  
  - 1 and 2 are on the inner side (closest to the center of the dish).
  - 3 and 4 are on the outer side (closest to the edge of the dish).
  - 1 and 3 are on the panel left edge when looking from the primary focus, 2 and 4 on the right side.
  - 5 is at or near the center of the panel.

Positive screw settings mean that the panel has to move closer to the primary focus (“up”).

References